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A geologic reconnaissance of the Whitefish Range Flathead and Lincoln Counties Montana

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A GEOLOGIC RECONNAISSANCE

OF THE

WHITEFISH RANGE

FLATHEAD AND LINCOLN COUNTIES, MONTANA

by

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ABSTRACT

The whitefish Range is located west of and adjacent to Glacier National Park in northwestern Montana.

The major rock types of the range are Precambrian argillites, metargillites, argilleceous magnesian limestone, quartzites and basic lavas, dikes and sills. Mississippian limestones and Pennsylvanian sandstones are exposed in the northeast part of the area and a small exposure of Devonian limestone occurs in the northwest part. Tertiary lake beds are exposed in a few places along the North Fork of the Flathead River and along some of its tributary streams. Glacial till covers most of the valley floors and extends well up onto the mountain slopes.

Reconnaissance mapping in 1953-54 revealed a major west dipping overthrust fault along the northeast edge of the range. Precambrian sediments of the Ravalli group form the overriding thrust sheet and Mississippian and Pennsylvanian sediments in both normal and inverted sequence underlie the sheet. At the International Boundary erosion has cut through a portion of the thrust sheet to isolate a klippe. The fault disappears to the southeast under the glacial till of the North Fork of the Flathead Valley.

INTRODUCTION

General Statement

Very little has been published on the geology of the Whitefish Range. In order to increase knowledge and perhaps facilitate economic development of the region, Great Northern Railroad initiated reconnaissance work in the summer of 1953. The reconnaissance was focused primarily on known exposures of Paleozoic strata and on exposures of any other strata of similar or younger age. Secondary attention was given to the Precambrian rocks of the area.

The area described in this report is located in northwestern Montana, and includes the northwestern portion of Flathead County and the northeastern portion of Lincoln County. The area lies between the North Fork of the Flathead River and the Stillwater River, and extends from the main Flathead Valley north to the International Boundary. The North Fork of the Flathead River forms the west boundary of Glacier National Park. (see Fig. 1) The Whitefish Range, of this report, includes all of the mountainous area in this region.

The western edge of the area parallels U. S. Highway 93 and a good graveled Forest Service road extends from Columbia Falls to the International Boundary along the eastern edge of the area. A narrow graveled road crosses the middle of the Whitefish Range in the vicinity of Red Meadow Creek, a tributary of the North Fork of the Flathead River. Forest Service trails provide the main access to the interior of the Whitefish Range, although a few intermittently maintained logging roads extend a few miles into several of the drainages.

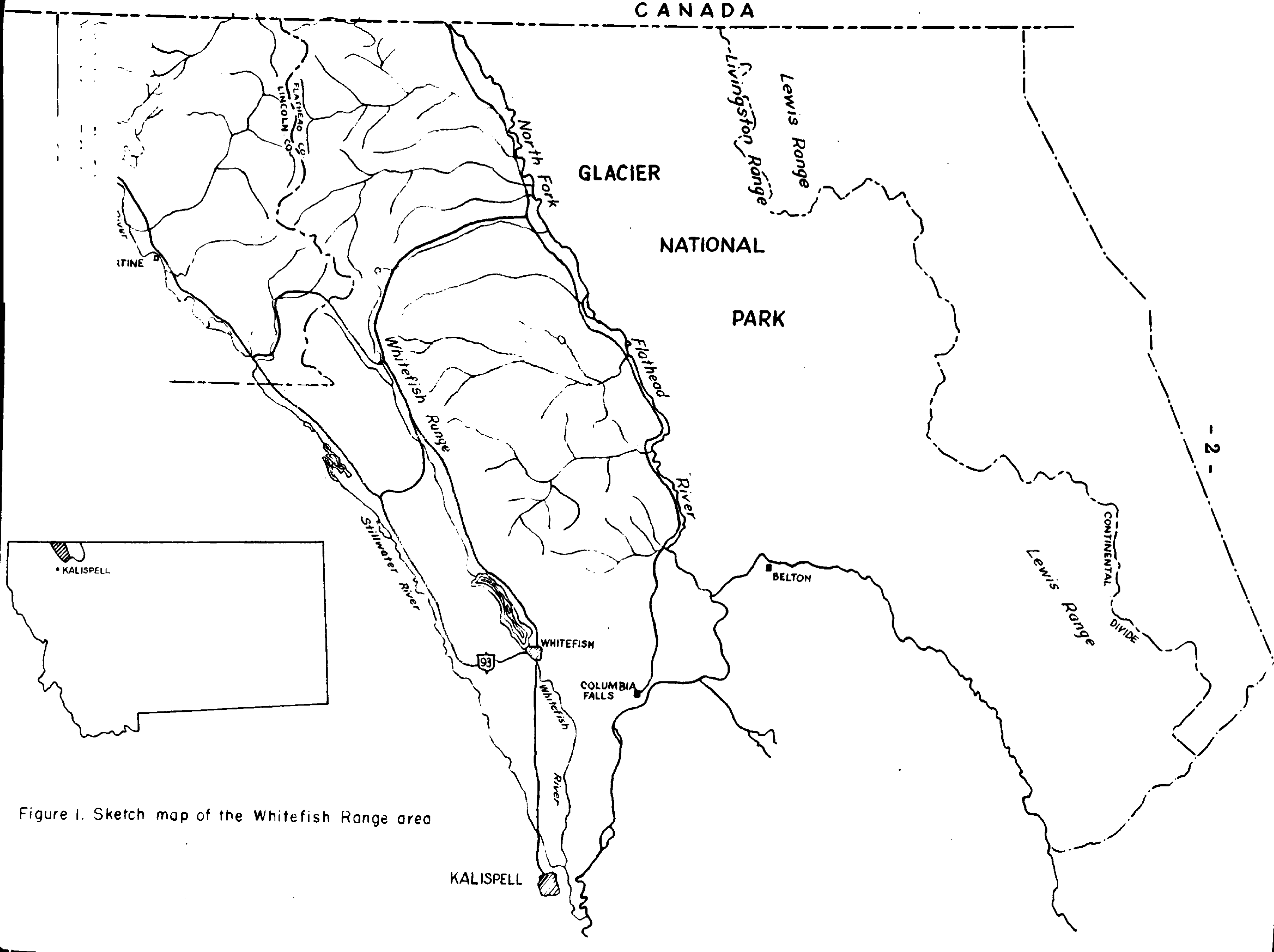

Figure 1. Sketch map of the Whitefish Range area

Reconnaissance was carried on during the summer of 1953 and part of the summer of 1954. An area of approximately 1250 square miles was studied.

Previous Work

With the exception of the early work of Daly (1912) along the International Boundary, very little systematic geologic work has been done in the Whitefish Range. The earliest known observations were made by George Gibbs in 1860 during the exploration of the International Boundary of the northwestern United States. The manuscript of the expedition containing the general and scientific records was lost before printing (Baker, 1900). However, Gibbs (1874) published a paper on the area and although it was geographical in nature it contained some brief geological references. Dawson (1885) and Willis (1902) visited parts of the area near the International Boundary, and Erdmann (1947) made detailed studies of the geology of small areas selected as possible damsites along the North Fork of the Flathead River. Other published papers that deal with the region in a general way include those by Schofield (1914, 1920, 1922), MacKenzie (1916), Rose (1918), Shepard (1922, 1926), Clapp and Deiss (1931), Clapp (1932), Link (1932), Hume (1932, 1944), and Pardee (1950). Other papers having an indirect bearing on the area have been published by various authors in the bulletins of the Canadian Geological Survey.

Acknowledgements

The writer wishes to express his sincere appreciation to Dr. K. P. McLaughlin for his help and direction both in the field and in the preparation of this report; to the Great Northern Railroad Company and especially A. J. Haley and R. A. Watson of the Mineral Development Department under whose sponsorship the field work was done during the summer of 1953; and to the many residents of the area and members of the U. S. Forest Service whose freely given information on trails, and

accessibility of areas greatly facilitated the field work.

Topography

The Whitefish Range is the southern extension of the Galton and the MacDonald Ranges of Canada.

Dawson(1885, map) and later Leach (1902, p. 73-74) working north of the International Boundary, recognized two distinct ranges west of the Front Range of the Rocky Mountains. The two ranges are stiuated between the valley of the North Fork of the Flathead River and the Rocky Mountain Trench, and are separated by the long straight valley of the Wigwam River. Dawson called the range east of the Wigwam River the MacDonald Range, and the range to the west the Galton Range. Willis, on his map (1902, p. 309) showed the Galton Range extending south to the Flathead Valley and (1902, p. 325) placed the southern extremity of the MacDonald Range at Yakinikak (Trail) Creek.* Clapp and Deiss (1932, p. 14) used the name Whitefish Range for the mountains lying between the North Fork of the Flathead River and the Stillwater River. The U. S. Forest Service currently uses Whitefish Range for all of the area except the northwest corner where the name of Glaton Range is retained for the mountains northwest of Wigwam and St. Claire Creeks.

The highest elevations in the area occur in the northern part near the International Boundary, where the crests of some of the peaks approach 8000 feet. The greatest relief also occurs in the north portion along the west side where the Tobacco Plains, at an elevation of less than 3000 feet, are adjacent to the mountains.

The general summit-level of the range descends gently to the southeast where few peaks higher than 7000 feet are encountered. The

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* The officially recognized name is Yakinikak Creek. The name Trail Creek, however, prevails locally.

evenness of the crests and ridges indicates that an uplifted and dissected peneplane surface forms the present range.

The Whitefish Range trends approximately N. 30° W., and parallels the Lewis and Livingston Ranges which lie just across the North Fork Valley to the east. The high serrate peaks of the Lewis and Livingston Ranges present a striking contrast to the lower crests of the Whitefish Range where only a few peaks rise above timber line.

The Flathead River, tributary to the Columbia River, is the main drainage of the region. The North Fork of the Flathead, which drains the eastern slope of the Whitefish Range, flows south from its headwaters in British Columbia and joins the Middle and South Forks to form the main Flathead River east of Columbia Falls. The Flathead River flows west across the southern end of the Whitefish Range then turns abruptly south. The Stillwater and Whitefish Rivers, which drain the southwest portion of the Range, flow south and southeast to join the Flathead River before it enters Flathead Lake. The Tobacco and Wigwam Rivers, which drain the northwest part of the area, flow north and northwest to join the Kootenai and Elk Rivers respectively. The Elk River flows west into the Kootenai River, a tributary of the Columbia River.

Cultural Development

There are no settlements within the Whitefish Range, but the towns of Eureka, Whitefish, Columbia Falls, and several small settlements between Eureka and Whitefish are located around its margins. Post offices are maintained in the North Fork of the Flathead Valley at Polebridge and at the International Boundary (Trail Creek). There are few permanent residents in this valley, but the cool summers and the proximity to Glacier Park attract numerous summer vacationists, and the seasonal logging industry and Forest Service activity help to swell the normal population during the warmer months.

Logging, although restricted seasonally by heavy winter snows and subsequent heavy spring runoff, is the chief occupation of the area. Small herds of cattle are grazed and some hay is grown in the valleys by the few permanent residents of the area. A very limited amount of fur trapping is carried on under government supervision during the winter months.

Climate and Vegetation

The temperature of the region is low because of relatively high altitude and latitude, and distance from the ocean. Precipitation is moderate and not subject to wide seasonal variations. Much of the precipitation falls as snow during the colder months. There is, however, no distinct wet and dry season as in the area to the west, and showers occur throughout the summer months. A summary of reports compiled by the Weather Bureau of the United States Department of Agriculture (1930; 1941, p. 955-956) at Columbia Falls, Belton, and Fortine gives the following:

	Columbia Falls	Fortine	Belton
Annual precipitation (inches)	21.49	17.70	26.65
Annual snowfall (inches)	70.4	54.7	119.1
Mean temperature (degrees Fahrenheit)	43.2	41.2	42.4
Highest recorded temperature (degrees Fahrenheit)	103.	107.	101.
Lowest recorded temperature (degrees Fahrenheit)	-40.	-47.	-42.

Because of the higher elevations of the mountains and the narrowness and depths of the valleys within the Whitefish Range, the corresponding temperatures are lower.

A dense forest of conifers covers most of the Range from the valley floor to the tops of all but the highest peaks. Dense thickets of brush are generally present on all but the highest slopes. Man-made clearings in the valleys, occasional natural meadows, talus slopes, cliffs, and burns provide almost all of the areas in which visibility was not restricted to less than 100 feet during the field season.

Glacial Geology

Evidence of glacial action is abundant throughout the area. Alpine glaciation has been extensive throughout the Whitefish Range especially in the higher northern part. Daly (1912, p. 584) considered the topography of the Whitefish Range to have been largely shaped by local cirque glaciers. In the Rocky Mountain Trench and, to a lesser degree, in the Valley of the North Fork of the Flathead River the thick accumulations of glacial drift that underlie the valley floors and extend well up the slopes of the mountains attest to the existence of the great ice sheets that advanced through the valleys.

Erdmann (1947, p. 127) found evidence of two, and possibly of three, advances of ice sheets, the youngest belonging to the Wisconsin glacial stage. The earlier advances appear to have followed the same path as the later Wisconsin glaciers whose paths may be traced fairly accurately. Erdmann states:

> "The main lobe of the Wisconsin Cordilleran Ice Sheet moved southward through the Rocky Mountain Trench west of the Whitefish and Swan Ranges. Another smaller lobe descended Flathead (North Fork) Valley, splitting into two parts on the north end of Apgar Mountain. The west (right) branch continued on down Flathead (North Fork) Valley to the north end of Teakettle Mountain where it was largely deflected to the southwest, uniting with the lobe in the Rocky Mountain Trench at Parker Hill, five miles north of Columbia Falls."

Daly (1912, p. 584-85) referred to the ice lobe that occupied the North Fork of the Flathead Valley as the North Fork Glacier and estimated it to have been greater than 2000 feet thick at the International Boundary. The thickness of the main ice sheet in the Rocky Mountain Trench was estimated by Daly to have been greater than 5000 feet.

Typical U-shaped valley profiles attest the movements of valley glaciers which merged with the main lobe of the ice sheet occupying the Rocky Mountain Trench to the west and the smaller secondary lobe occupying the Valley of the North Fork of the Flathead River on the east. The divide separating the eastward and westward flowing ice was considered by Daly to have been between Wigwam River and the North Fork of the Flathead River.

STRATIGRAPHY

The Whitefish Range is composed mainly of Precambrian rocks of the Belt series. In the northwest corner of the Range, at the International Boundary, rocks of Devonian age crop out in a small, narrow area along the edge of the mountain front. The northeast part of the Range includes Paleozoic strata of Mississippian, Pennsylvanian, and Permian (?) age which extend from north of the International Boundary to Whales Buttes approximately ten miles south of the Boundary. In the North Fork of the Flathead Valley semi-consolidated Tertiary strata unconformably overlie the older rocks. In the valleys and along the lower slopes glacial debris and alluvium of Pleistocene and Recent time irregularly cover the older rocks. A few miles north and northeast of the Range, rocks of Cambrian, Silurian, Triassic, Jurassic, and Cretaceous age crop out in addition to the above mentioned strata.

Proterozoic - Belt Series

Precambrian rocks within the Whitefish Range includes, from oldest to youngest, the Ravalli, Siyeh and Missoula groups of the Belt series. The series is composed predominately of strongly indurated sediments of shallow water origin. Cross-bedded and ripple-marked argillites, metargillited, siliceous dolomitic limestone and quartzite make up the major rock types of the series. In their original state these sediments were fine grained argillaceous siltstone with lesser amounts of argillaceous magnesian limestone and still less sandstone. Before deposition of the Missoula group, the two older groups were intruded by basic igneous rocks and were locally covered by one or more submarine lava flows. Following deposition of the Missoula group, and possibly before deposition had ceased, the igneous activity was resumed and the Missoula group was covered locally by two or more basic lava flows.

Dawson (1885) first described the Precambrian rocks in localities adjacent to the area. He confused the Siyeh group with Devonian-Carboniferous limestones and accordingly called the sediments below the Siyeh, Cambrian, and those above, permo-Triassic. Willis (1902, p. 317-24) recognized Dawson's error and dated the rocks of the Lewis and Livingston Ranges as Precambrian of Algonkian age and described them as the Lewis series. Daly (1912, p. 97-110) described the Precambrian rocks of the Whitefish Range at the International Boundary and correlated them with the Lewis series. Daly, however, dated the rocks above the Altyn limestone as Cambrian and on the basis of lithologic differences in the Whitefish Range used formation names different from those of the Lewis series. Daly named this series of rocks the Galton series. Schofield (1914, p. 88-89) correlated the Galton series with the Purcell series and (p. 91) showed evidence that the Belt series was Precambrian. Wilson, et al. (1924, p. 91-92) tentatively correlated rocks of the 49th parallel series with the Belt series farther south, and Clapp and Deiss (1931, p. 690-693) advanced the following correlation of the Belt series of western Montana.

Galton Series	Lewis Series	Belt Series
Phillips	Kintla	Missoula group
Gateway	Shepard	
Siyeh	Siyeh	Siyeh group
Wigwam	Grinnell	
MacDonald	Appekunny (upper)	Ravalli group
Hefty	Appekunny (lower)	
Altyn	Altyn	

The strata of the Galton and Lewis series below the top of the Siyeh are similar enough to warrant common formation names. Because the terminology of the Lewis series was named first and has gained a widespread use in northwestern Montana the author has used that terminology wherever possible.

(Ravalli Group)

The Ravalli group, according to Clapp, (1932, p. 22) includes in ascending order the Altyn, Appekunny, and Grinnell formations. Willis (1902, p. 332) felt that the Grinnell and Appekunny were possibly phases of one formation and that the line of distinction between them was one diagonal to the stratification. Erdmann (1947, p. 130) noted an interfingering of Grinnell and Appekunny rock types, apparently confirming Willis' hypothesis.

The Altyn formation, as exposed in the Whitefish Range, consists of light-gray to buff, thin-bedded, siliceous limestone, weathering white to cream color. The only exposures of Altyn observed in the Range occur between Yakinikak (Trail) Creek and the International Boundary in the vicinity of Mt. Hefty and Mt. Thoma.

The lower Appekunny (Hefty formation of Daly) immediately overlying the Altyn east of Mt. Hefty, consists of red, thick-bedded, coarse-grained sandstone and quartzite with interbedded red and green argillite. The upper Appekunny (MacDonald formation of Daly) consists of dull gray-green, thin- to thick-bedded-argillites, with thin interbeds of tan quartzite. Ripple marks and mud cracks are common.

The Grinnell argillite forms the top of the Ravalli group and consists of maroon to red, ripple-marked and mud-cracked, hard and dense, thinly laminated massive argillite and quartzite with interbedded gray-green argillite.

(Siyeh Limestone)

The Siyeh limestone, as described and correlated by Clapp and Deiss (1931, p. 676-696), consisted of upper and lower limestone units with an intervening bed of red argillite. The upper limestone is known in various localities as the Upper Siyeh, the Upper Wallace, or the Helena limestone. The lower limestone has been called the Lower Siyeh, the Lower Wallace, or the Newland limestone. The middle argillite is known variously as the "red band in the Siyeh," the Empire, the Grayson, or the Spokane argillites.

In the Whitefish Range the middle red argillite was nowhere recognized and the Siyeh, as described, consists of one undivided formation.

The Siyeh limestone consists of yellow- to buff-weathering dark bluish gray to dark greenish gray, impure siliceous and magnesian limestone with intercalated green argillite and dolomitic argillite. The buff and yellow weathering is often obscured by growths of dark lichens. The limestones are predominantly massive with lesser thin-bedded limestone alternating with the massive beds throughout.

(Missoula Group)

Willis (1902, p. 324), in the Lewis and Livingston Ranges, subdivided the strata above the Siyeh limestone into the Shepard and Kintla formations. Daly, in the Galton (Whitefish) Range, also subdivided a greater thickness of strata above the Siyeh into the Gateway and the Phillips formations. Erdmann (1947, p. 131-32) measured a thickness of Missoula group of approximately 25000 feet in the North Fork of the Flathead Valley from the junction of Nicola Creek with Big Creek to Glacier View damsite, but made no attempt to subdivide the group into formations. The lowest part of the Missoula group grades upward from the Siyeh limestone in the south and eastern part of the Range. In the northwestern part of the area the Siyeh-Missoula contact is marked by Purcell basalt similar to that of the Lewis series. The lowermost strata of the Missoula group consist predominantly of light to dark greenish-gray argillite and quartzite interbedded with light greenish-gray limestone and dolomite which is mostly thin-bedded. The limestones and dolomites are gradationally replaced by red argillite. The middle part of the Missoula group consists predominantly of reddish-tan to brown argillites and quartzites with interbedded light green argillites. Near the top of the group, gray-green again becomes the predominant color. Ripple marks and mud cracks are common throughout the group. Daly (1912, p. 108) noted the lack of contemperaneous lavas within the formations above the Siyeh in the Whitefish Range, as contrasted to the lavas present above the Siyeh in the adjoining Lewis and Livingston Ranges. Lava flows in the Missoula group are exposed in the valleys of Hay Creek and Red Meadow Creek to the south, and Erdmann (1947, p. 132) noted the presence of lava flows exposed in the vicinity of Glacier View Mountain in the southeastern part of the area.

Paleozoic

Paleozoic time is represented by outcrops of Devonian limestone in the northwest, and by Carboniferous limestone and quartzite in the northeast parts of the Whitefish Range. Older Paleozoic formations are absent, but Scofield (1922) mapped the Precambrian-

Cambrian contact a few miles to the north across the International Boundary and Cambrian and Silurian sediments have been reported near Akimina Brook a few miles to the northeast (Hume, 1932, p. 62).

Daly (1912, p. 110) first noted the occurrence of limestone at the northwest edge of the map area, and on the basis of fossil evidence dated it as Devonian in age and equivalent to the Jefferson formation. Dawson (1885, p. 54) noted exposures of limestone and quartzite along Yakinikak (Trail) Creek in the northeast part of the map area and tentatively dated them as Carboniferous. Later, Willis (1902, p. 325) noted the same exposures, described the limestone, dated it on fossil content as younger than the Madison limestone, and named it the Yakinikak limestone.

Daly (1912, p. 111) assigned limestone at the International Boundary along the east edge of the Whitefish (MacDonald) Range to the Mississippian period.

Clapp (1932, map) showed undifferentiated Carboniferous strata as far south as Whale Buttes on the east edge of the Whitefish Range. The topographic expression of Whale Buttes and their alignment with the strike of exposed Carboniferous strata, suggests that the buttes are underlain by Carboniferous rocks. The buttes, however, are covered by a heavy mantle of glacial debris which support a thick brush and forest cover and no exposures or significant amounts of float could be found.

Devonian Period (Palliser Formation)

A small narrow belt of Devonian limestone crops out along the extreme northwest edge of the map area forming a low ridge in front of the steeply rising front of the Whitefish Range. The exposed stratum is dark-gray to gray-brown, dense to finely crystalline, thick-bedded to massive, cliff-forming limestone. The limestone weathers light gray, is fossiliferous in part, and commonly contains black chert nodules. The weathered surfaces of the rock have a pitted rough appearance. Fresh-fractured surfaces usually produce a fetid odor.

Exposures of the limestone are confined to the immediate vicinity of the International Boundary and are hidden under glacial debris to the south and west. The topographic expression of the gently south-sloping ridge and occasional pieces of float suggest that to the south the ridge is underlain by the limestone.

A comparison of the faunal assemblage collected by Daly (1912, p. 112), and of the lithology of the limestone with those of Devonian sections to the northwest (deWit and McLaren 1950), suggests the exposure is a part of the Morro member of the Palliser formation, a correlative of the Three Forks and uppermost Jefferson formations (Andrichuk 1951, p. 2380) (see fig. 2).

Mississippian Period (Rundle Formation)

Most of the Mississippian succession of sediments in southeastern British Columbia are included in the Banff and Rundle formations (Beales 1950). The Rundle-Banff contact appears to be gradational and is based on the change from Banff type shaly limestone to Rundle type massive crinoidal limestone. Weller et al. (1948, Plate 2) have correlated the Banff and Rundle formations with the Hannan formation (Deiss 1943, p. 228-31) along the east front of the Rocky Mountains in northwestern Montana (see fig. 2). The Rundle, while classified as Mississippian, may transgress the Pennsylvanian boundary as Shimer (1926, p. 5), in the Banff area, and Warren (1932, p. 33), in the Crowsnest Pass area, have reported Pennsylvanian fossils in the Rundle formation. The upper contact of the Rundle with the overlying Rocky Mountain quartzite is apparently conformable,

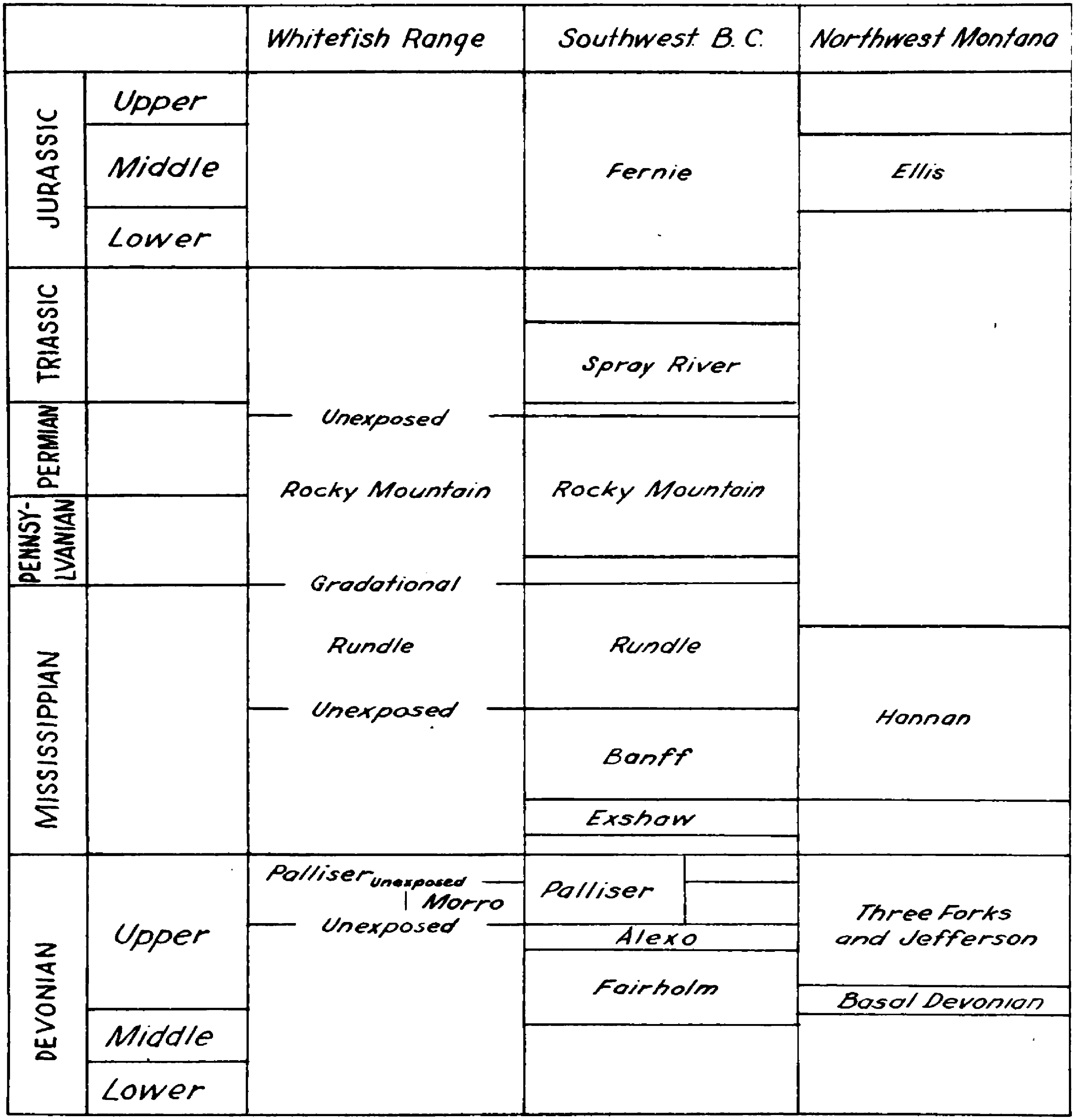

Figure 2. Correlation chart of the Paleozoic formations of the Whitefish Range, southwestern B.C. and northwestern Montana.

although thinning of the Rundle to the north, combined with the absence of upper faunal horizons, suggests an unconformable overlap (Weller et al. 1948, p. 138).

Limestone of Mississippian age crops out along the eastern part of the Whitefish Range from above the International Boundary south to Whale Creek. In Yakinikak (Trail) Creek Canyon more than 450 feet of the formation is exposed in the creek bed and along the walls. Blackstone (1934, p. 91) found a predominance of Chester and Meremac fossils in the limestone and dated it as upper Mississippian in age. The faunal assemblage, the lithology and the stratigraphic relationship of the limestone to the overlying quartzite indicate that the limestone is a part of the Rundle formation. Willis (1902, p. 325), in his description of the stratigraphic position of the limestone, states:

> "It (the limestone) is without upper stratigraphic limit, but rests conformably on a quartzite which is unconformable on Algonkian strata. The quartzite is about 25 feet thick and it and the limestone lie in a nearly horizontal position."

Investigation of the exposed sediments in Yakinikak (Trail) Creek, and through the map area, indicates the lower limit of the limestone to be covered. Willis may have erroneously considered the sandy beds of the lowest exposed Rundle to have been of a different formation, but in no locality was the Rundle observed to overlie Algonkian strata. Willis was also mistaken about the upper limit of the limestone as at least 650 feet of quartzite was observed conformably overlying the limestone.

The Rundle formation consists of gray and brown-weathering, light to dark-gray and brown, alternating massive and thin-bedded limestone and dolomite with occasional interbedded sandstone and siltstone. The coarsely crystalline beds are usually cliff formers.

Black chert nodules and layers are abundant throughout the formation.

The following detailed stratigraphic section of the Rundle formation was measured:

Section measured along the north side of Yakinikak (Trail) Creek from the road cut west of Thoma Creek bridge, up Thoma Creek to the cliff-top on the east side, and thence east along Yakinikak (Trail) Creek to the contact of the Rundle limestone and Rocky Mountain quartzite (Sections 25, 26, 35, 36, T37N, R23W).

The base of the section is on the crest of a small anticlinal axis which trends nearly north-south at the road and turns northwestward to parallel Thoma Creek.

Measured by K. P. McLaughlin, C. Neill and G. L. Sweeney.

Unit Number	Description	Thickness
	Rocky Mountain Formation (Basal)	
38	Sandstone, light-gray to yellow, hard, weathers dark-brown to black, and quartzite, ferruginous, weathers brown to black; all crossbedded and some zones characterized by 1/4 inches to 1/2 inch pits on weathered surface.	
	Rundle Formation	
37	Sandstone, partially covered, friable, slightly dolomitic and white at base, becoming harder, ferruginous and more nearly quartzitic at the top.	5. 5'
36	Sandstone, nearly quartzitic, medium- to fine-frained, nearly white, irregularly cemented in part by dolomite.	11'
35	Dolomite, sandy, very light gray to nearly white, weathers light brown to buff; a few calcite filled veinlets and one 4 inch lens of chert.	4'
34	Unexposed.	21'
33	Dolomite, sandy, with nodules of dark gray to black chert; weathers buff. Beds up to 1 foot thick.	6'

Unit Number	Description	Thickness
32	Sandstone, medium-grained, very slightly calcareous, porous, pitted on surface, yellow, weathers brown to rusty.	5.5'
31	Dolomite, thinly interbedded with limestone, all sandy, light gray, with weathered surface of most of unit show sandy cross-bedding within the carbonate.	8'
30	Limestone, sandy, irregularly bedded, light gray, weathers light brown to buff.	5'
29	Dolomite, sandy, very light gray to white, weathers light brown to buff.	7.5'
28	Covered	5'
27	Dolomite, dense to finely crystalline, slight brecciated, purple chert in upper 3 feet; light to medium gray, weathers buff.	10'
26	Covered.	5'
25	Dolomite, sandy at base, brecciated through middle 5 feet, slightly conglomeratic in upper 3 feet; vari-colored, weathers buff.	12'
24	Dolomite, slightly calcareous in part, brecciated in upper 2 feet, dark gray to black in lower beds, light gray in upper beds, interbedded with dark green, hard dolomitic silty shale, weathers buff.	9'
23	Covered.	21'
	From the top of Unit 22 to stratigraphically higher beds is a distance of approximately 3/4 mile down Trail Creek. A survey of all exposures in this interval indicated that an average dip of 2° eastward prevails and that the actual stratigraphic interval involved is small.	

Unit Number	Description	Thickness
22	Limestone, medium crystalline to very coarsely crinoidal, gray to dark gray-brown. Chert nodules abundant as are brachiopod and coral fragments.	13'
21	Breccia of dense gray limestone, fragments up to 3/4 inches, in matrix of yellow, finely crystalline limestone. Very poorly exposed.	3'
20	Limestone, dense, gray, and medium crystalline, light gray. Very poorly exposed.	5'
19	Limestone, medium crystalline, gray, weathers gray, beds up to 1 foot thick; productid fragments in lower 1 foot, along with <u>Staurinceum</u> coral colonies. Chert lenses and nodules throughout.	9'
18	Dolomite, dense, thinly interbedded with black chert, light gray, weathers nearly white. Upper 3 inches contains specks up to 1/8 inch of very black, lustrous, flaky, soft material, possibly carbonaceous.	2'
17	Limestone, slightly dolomitic, fine- to medium-crystalline, beds 3 inches to 1 foot thick, gray, weathers gray. Lower 5 feet poorly exposed, brachiopods at 6 feet above the base.	7.5'
16	Limestone, slightly dolomitic, dense and finely crystalline, vugular, slightly fetid odor, beds 1 foot to 2 feet thick, scattered fossil fragments, dark gray to dark brown, weathers gray. Small zyphrentid corals at 50 feet above base of unit.	60'
15	Limestone, finely crystalline, silty and probably siliceous, hard, blocky, beds 6 inches to 1 foot thick, light and dark gray, weathers light brown.	20'
14	Unexposed, probably siltstone.	3'
13	Siltstone, slightly calcareous, dark gray	

Unit Number	Description	Thickness
	to black, and sandstone very fine-grained, slightly calcareous, light olive green, interbedded with soft black to gray siltstones and sandstones and dark green, non-calcareous, siliceous shale. Except for shales, the unit weathers light brown.	19'
12	Limestone, medium to very coarsely crystalline, essentially coquina in some zones, gray to dark brownish-gray. Basal 55 feet massive, cliff forming, upper 11 feet more thinly bedded, less resistant. Fossil fragments throughout, possible ostracodes at 40 feet above the base. An 8 inch oolitic bed at 60 feet above the base.	66.5'
11	Dolomite, finely crystalline to medium crystalline, dark gray at base, light gray at top, poorly exposed in mid-portion. Top 2 feet forms a prominent re-entrant in cliff.	11.8'
10	Poorly exposed. Near middle of interval is one outcrop; dolomite finely crystalline, gray, apparently grading up to very sandy dolomite or fine-grained dolomitic sandstone.	8.4'
9	Dolomite, finely crystalline, irregularly bedded with chert nodules and lenses, gray weathers light gray.	9'
8	Dolomite, finely crystalline, irregular bedded, gray to gray-brown, weathers dull gray at base, light gray at top. A few zones show slight porosity.	16.2'
7	Dolomite, irregularly dense and finely crystalline, massively bedded, chocolate brown to gray brown, weathers gray, weathered surface mottled as result of mixture of textures.	27.3'
6	Dolomite, finely crystalline, irregularly	

Unit Number	Description	Thickness
	bedded, gray to dark gray, fetid odor in lower part.	7'
5	Dolomite, fine- to medium-crystalline, massively bedded, fetid odor, gray to dark gray, irregular distribution of fine crystalline portions in upper 2 feet produces mottled agglomerate like appearances on weathered surface.	7.3'
4	Dolomite, finely crystalline, irregularly bedded, gray, weathers gray, upper 3 feet show abundance of small vugs and possible pinhole porosity. Petroliferous odor in upper 3 feet.	10'
3	Dolomite, silty at base, less silty at top, irregularly bedded, weathers to surfaces both smooth and with wavy laminations, dark gray at base, gray at top.	12'
2	Sandstone, very fine-grained, dolomitic, massive, light to dark gray, weathers to brown wavy laminated surface probably as a result of lamination of the sand or of irregularity of cementation, probably the latter. There is a suggestion of ripple marks on some surfaces. The lower 6 inches have been altered by solution. Vugular throughout.	7'
1	Sandstone, fine-grained, slightly dolomitic, beds 2 to 2.5 feet thick, yellow to olive green, weathers light brown.	10'
	Total thickness	459.5'

Pennsylvanian-Permian Periods (Rocky Mountain formation)

The Pennsylvanian sediments in southwestern British Columbia are included in the Rocky Mountain formation. The Rocky Mountain of the Banff area has been subdivided by Warren (1947, p. 1238) into two members. The lower dolomite and sandstone member is probably Pennsylvanian in age while the upper, consisting of dolomite, chert, phosphatic shale, and thin phosphate beds is probably Permian. The Rocky Mountain formation in southeastern British Columbia is in part overlain, apparently conformably, by strata believed to be Triassic in age, and in part overlain unconformably by the Jurassic Fernie Formation (McKay 1931, p. 16).

In the Whitefish Range the Rocky Mountain Quartzite is very well exposed along the valley of Yakinikak Creek. The exposed section consists of from 650 to 859 feet of gray, yellow, and brown, medium-to fine-grained, quartzite and sandstone weathering dark-brown to black, gray and pink. Dark green lichens, growing on some surfaces, occasionally obscure the weathering. The weathered surface of the lower 150 feet is characterized by deep pits from 1/4 to 1/2 inch in diameter. The contact of the Rocky Mountain formation with the underlying Rundle is gradational and the selection of the contact is arbitrary (pl. I B).

The following detailed section of the Rocky Mountain formation was measured along Yakinikak (Trail) Creek:

Section measured from just west of major talus slope across base of slope below road and up mountain side to crest. (Sec. 25, T37N, R23W)

Measured by Dr. K. P. McLaughlin, C. Neill and G. L. Sweeney.

Rocky Mountain formation. (All additional section above unit 46 has been removed by erosion.)

Unit Number	Description	Thickness
46	Sandstone, deeply weathered.	15'
45	Mainly talus covered, sandstone and quartzite.	20'
44	Sandstone, medium to fine-grained, yellow to brown, well cemented, massive, weathers gray and pink. Quartzite in a few zones. Strike - N 35° W. Dip - 9° SW.	66'

Unit Number	Description	Thickness
43	Covered - sandstone float. Within this interval the section crossed over an anticlinal axis which cannot be definitely placed. Thickness may be as little as 330 feet.	550'
42	Sandstone, medium to fine-grained, nearly black, friable, weathers dark brown to black, fetid odor.	7.5'
41	Covered.	15'
40	Sandstone, medium frained, light to dark gray, slightly dolomitic, poorly exposed, in part porous and with petroliferous odor. Few small vugs lines with black material (bitumen).	10'
39	Partially exposed. Sandstone, medium-grained, dark gray, quartzitic.	35'
	Total thickness	718.5'

Mesozoic

No exposures of Mesozoic strata were observed in the Whitefish Range although rocks of Triassic, Jurassic and Cretaceous age crop out immediately north of the area in British Columbia. Telfer (1933, p. 572) reported 300 feet of black buff weathering shale which he tentatively classified as Triassic near the International Boundary. On Cabin Creek MacKenzie (1916, p. 20) reported 2500 feet of white and dark gray sandstone and quartzite as Triassic in age, overlying Devono-Carboniferous limestone. The lithology, stratigraphic position and thickness of MacKenzie's Triassic (?) beds suggests the Rocky Mountain Quartzite of Pennsylvanian age.

The Fernie formation overlies the Triassic beds apparently conformably but taken over a wide area of southeastern British Columbia a pronounced disconformity exists (MacKay 1952, p. 5). The Fernie consists of a thick series of brown and buff marine shales with some beds of limestone and sandstone.

The Cretaceous of southwestern British Columbia and the Flathead area consists primarily of the Kootenai formation. The Kootenai formation is composed of a thick series of sandstones, shales, conglomerates and coal seams. The Fernie-Kootenai contact is apparently transitional from marine deposits below to predominately non-marine deposits above (Telfer 1933, p. 574).

Although Mesozoic strata were not recognized in the Whitefish Range, the proximity of the Fernie formation to the north suggests that at shallow depths it may underlie the glacial debris and possibly Tertiary lake beds along the mountain front in the vicinity of the International Boundary.

Cenozoic

Tertiary Period (Kishenehn Formation*)

Thin, evenly bedded sediments, probably lake beds, are exposed in cut banks along the North Fork of the Flathead River (pl. I C) and in the lower valleys of some of the tributaries of the river.

Dawson (1885, p. 52) first recognized the lake beds in British Columbia and later Willis (1902, p. 327) recognized similar beds in Montana. The name Kishenehn was first applied by Daly (1912, p. 86) who took the name from Kishenehn Creek a tributary of the North Fork of the Flathead River. Concerning the origin of the beds Willis (1902, p. 327-28) states:

> "These deposits are called lake beds because they are very distinctly and evenly stratified. They consist of fine sediment, such as would settle from quiet water only, and they occur in a valley of such moderate width between mountains of such height that no condition of

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* Also spelled Kishinena, Kishenena.

> alluvial accumulation seems appropriate. It is possible that the lake was at times shallow like a flooded river. It is probable that it was some time reduced to the proportions of a river. It is certain that during considerable intervals some areas were marshes; but admitting that a lake may pass through various phases of depth and extent, the term lake bed best describes these deposits."

Neither the top nor the bottom of the formation has been observed and no accurate estimate of thickness is available. Daly noted 250 feet of different beds exposed along the North Fork of the Flathead River and believed they represented a total thickness of 500 feet. MacKenzie believed that "it apparently reaches a thickness of 1500 feet but may be much thicker." Erdmann (1947, p. 134) considered the 700 feet of the formation penetrated at Kintla Well, Sec. 12 T26N R22W, acceptable as a minimum thickness and estimated a possible thickness of 8400 or more feet between Coal Creek and the mouth of McGee Creek.

Clark (1954, p. 109) believed the lake beds were deposited in an elongate down faulted basin and Erdmann (1947, p. 134) stated that sedimentation with simultaneous deepening of the valley by faulting was necessary to explain for the thickness of the sediments.

Erdmann (1947, p. 134) recognized two facies of the Kishenehn formation in the North Fork of the Flathead Valley. The older facies is gray and brown clay and siltstone with layers of impure lignite and thin lenses of sandstone. The younger facies consists of light gray to red, clacareous siltstone, and fresh water limestone, and soft, light greenish-gray siltstone, sandstone, and drab clays. The presence of occasional intercalated boulder beds in the finer grained sediments indicates flood deposits. Erdmann believed that the structural relationships suggest that the carbonaceous facies may be considerably older than the calcareous and clay facies. The calcareous facies was not observed in the map area but MacKenzie (1916, p. 37) observed buff soft fossiliferous calcareous rock, to which he applied the term marl, on Cauldery Creek just north of the map area and rocks of similar description were observed along Bowman Creek on the east side of the North Fork of the Flathead Valley.

The rock underlying the Tertiary strata are unknown because at no locality has the base of the Tertiary been observed. Theories regarding the underlying rocks depend on theories of the structural origin of the area. Some interpretations of structure would necessitate the lake beds to be underlain by Paleozoic or younger strata while others would necessitate the underlying rocks to be Precambrian in age and overthrust onto Paleozoic or Mesozoic rocks.

The exact age of the Kishenehn is uncertain. MacKenzie (1916, p. 37) and Daly (1912, p. 87) believed it to be Eocene; Dawson (1885, p. 52) noted the resemblance to Miocene beds in Central British Columbia; Willis (1902, p. 327) noted a resemblance to Miocene or Pliocene beds near Missoula, Montana; and Erdmann (1947, p. 135) designated it as Oligocene or Miocene on structural evidence. Eardley (1947, p. 1176) found that latest Miocene or early Pliocene was indicated wherever fossils were found in the Tertiary deposits of the late Cenozoic Trenches in the Rocky Mountains.

Quaternary Deposits

Quaternary deposits consist of Pleistocene glacial till, Recent alluvium and, to a small degree, talus and slump.

The Pleistocene glacial till consists of sandy, silty, and clayey deposits containing loose gravel and boulders, some striated, of various mixed sizes, and including a few large fragments which evidently could not have been rolled by water. The deposits are in the form of terminal, lateral, and ground moraines and in most places cover the valley floors and the valley walls well up onto the mountain slopes. Daly (1912, p. 586) estimated a 200 feet average thickness of the Glacial till in the western valleys. The till is, however, of undetermined thickness and covers the older rocks of various ages. Precambrian and Paleozoic formations furnished much of the rock fragments in the till. The soft Tertiary rocks are not present in recognizable form but are undoubtedly included in the fine material. Erratic igneous boulders foreign to the region are found intermingled with the common local rock types in the morainal till.

Recent alluvium, for the most part derived from reworked glacial debris is found in and along the stream and river channels. Talus deposits are found in the vicinity of steeper slopes and cliffs but are of limited extent as their period of growth has been limited to the time since the last glaciation.

Igneous Rock

Extensive exposures of extrusive lavas and intrusive dikes and sills are found associated with the Precambrian sediments in the mountainous areas along the International Boundary from Glacier Park to the westward. Willis (1902, p. 324) first noted an extrusive sheet overlying the Siyeh limestone in the Lewis and Livingston Ranges. Daly (1912, p. 162-165) called this sheet the Purcell lava and used it as an important criterion in correlating Precambrian strata for nearly 100 miles along the International Boundary. Erdmann (1947, p. 137) noted the petrographic similarity between the extrusive and intrusive bodies and grouped them all under the term Purcell basalt.

In the northeastern portion of the Whitefish Range an extrusive sheet approximately 200 feet thick overlies the exposed Siyeh limestone. In the southeast portion, however, there is no evidence of an extrusive separation or of a disconformity between the Siyeh limestone and the overlying Missoula group. Some dikes and sills occur within the Missoula group of the southeast part of the area, and near the top of the exposed Missoula group two lava flows are exposed in the vicinity of Glacier View and Huckleberry Mountain. Erdmann (1947, p. 138) estimated the base of the lower flow to be about 22,000 feet above the Siyeh-Missoula contact. The lower flow is about 100 feet thick and approximately 1,000 feet of Missoula Group sediments separate it from the upper flow. The upper flow is 160 feet thick and contains pillow structures at the base which suggests that the lava was at first extruded into wet mud or shallow water.

The exposed igneous rock is generally dark green to purple in color and is in part both vesicular and amygdaloidal. The extrusive sheets are dense to fine-grained basalt whereas the intrusive dikes and sills are medium-grained diabase. Daly's analysis (1912, p. 209) of the intrusive rocks shows them to be chemically related to the basalts.

GEOLOGIC STRUCTURE

Regional Structure

In general the outstanding structural features of northwestern Montana are a series of depressed elongate basins alternating with uplifted and tilted rectangular ranges having a general northwest-southeast trend. Apparently most of the ranges and valleys are fault-founded blocks. This apparently simple structural pattern is the result of a long and complex diastrophic history which evidence suggests may not yet be ended. (Clapp, 1932, p. 18, 27; Erdmann, 1947, p. 77; Eardley, 1947, p. 1176).

Clapp (1932, p. 24-27) classified the faults of northwestern Montana into five sets in order from oldest to youngest: (1) steeply dipping strike or longitudinal thrust and under thrust faults; (2) low angle west dipping overthrust faults typified by the Lewis overthrust; (3) transverse steeply dipping normal or vertical faults; (4) transverse steeply dipping reverse or thrust faults and (5) normal strike faults of low dip. A sixth type was recognized but because the movements had taken place along older faults this type was not readily distinguished.

The faults of set (1) east of the Lewis and Clark Range and east of the Lewis thrust were observed by Clapp (1932, p. 19) to dip steeply to the southwest while those between the Lewis and Clark Range and the Rocky Mountain Trench, were observed to dip steeply to the northeast. As the compressive forces apparently acted from the southwest, the northeast dipping faults were considered to have been underthrust faults. These include the great Swan, Mission, Flathead and Roosevelt faults (see fig. 3) which along with the overthrusts of set (2) were considered to have been the most important factors in the development of northwestern Montana's structural features.

Clapp believed the sequence of mountain building to have followed the numerical sequence of the above fault classification and stated (1932, p. 27):

> "It appears as if the forces causing faulting acted from the southwest, first uplifting and folding the rocks then breaking them along the longitudinal thrust faults. Later, the deformation continued to such an extent that relief from the stresses came by overthrusting. The two sets of transverse faults seem to be a still later effect of the continuing pressure from the southwest and consequent elongation to the northwest and southeast, after further uplift beyond the great heights to which the mountains had attained was impossible, because it was easier for the rocks to move horizontally, to the northwest

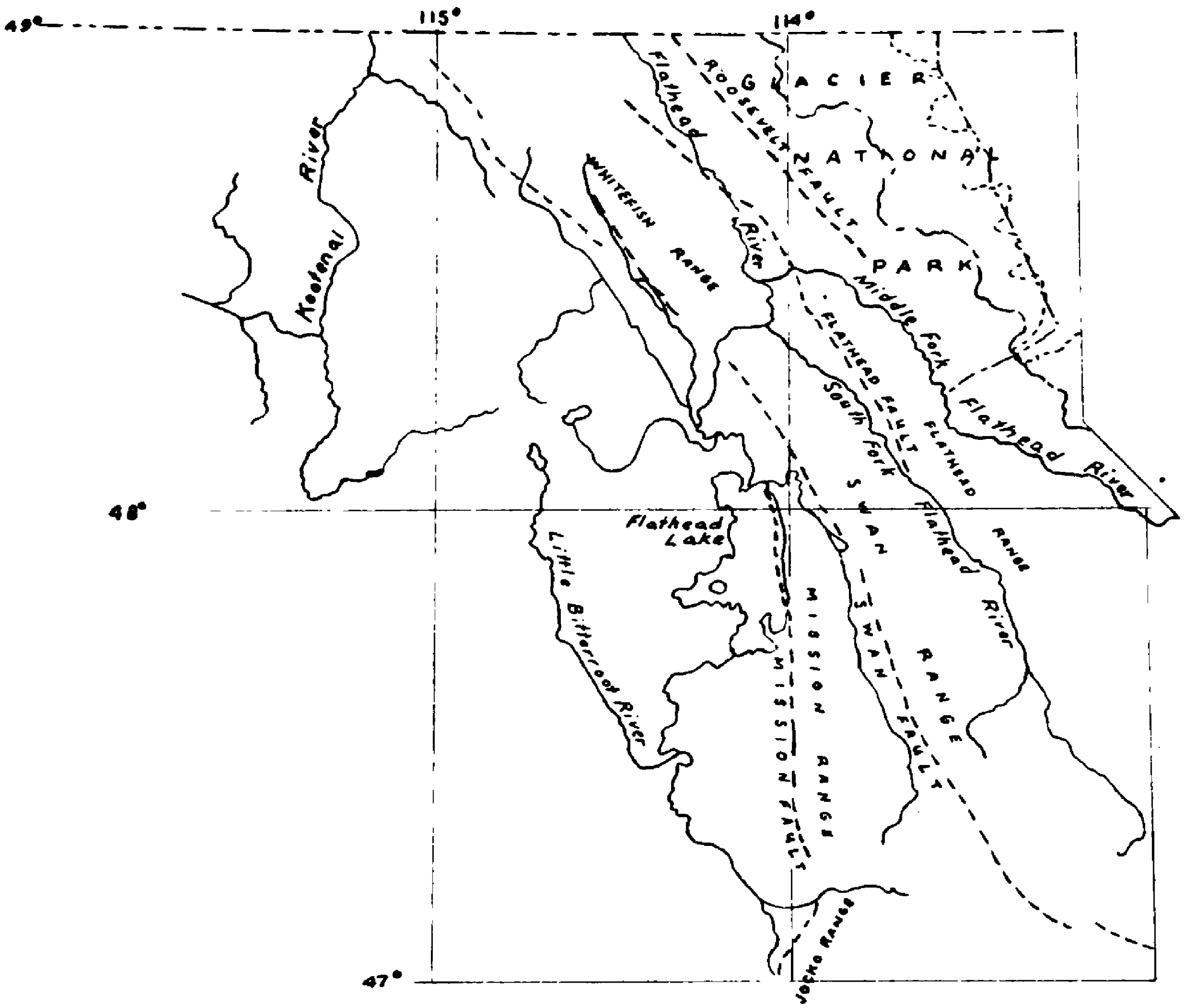

Figure 3. Sketch map showing major faults of a portion of northwestern Montana.

> and southeast by crushing and breaking, than to be uplifted higher. Apparently, as the compressive forces acting from the southwest lessened, normal strike faults of low dip relieved the vertical pressure resulting from the great height of the uplifted rock."

In this sequence of orogenic activity the steeply dipping Swan, Flathead, Mission and Roosevelt faults, which bound the west sides of the Swan, Flathead, Mission and Livingston Ranges respectively, were formed before the low angle Lewis overthrust.

Erdmann (1947, p. 78) believed that the first and second events of faulting as outlined by Clapp were reversed and that the uplifting of the rocks and overfolding from the west culminated in the Lewis overthrust. The second event was the warping of the overthrust followed by the high angle thrust faulting or upthrusting which produced the Swan, Flathead and Roosevelt faults and resulted in the development of the structural valleys and the relative uplift of the mountain blocks. The final orogenic event was the renewal of movement along the margins of the structural valleys and mountains. These latest movements tilted the Tertiary lake beds which had been deposited in the valleys.

Pardee, (1950, p. 403) while recognizing the uplift and overthrusting resulting from compressional forces in northwestern Montana, interpreted the present mountain and valley structure to have been the result of block faulting similar to that of the Basin and Range Province. The block faulting occurred when deeply buried compressive forces elevated the superincumbent layer, which was free from horizontal compression but under tensional strains, and caused it to crack and split. The block faulting in northwestern Montana was considered to have occurred in part along the strike of Clapp's Swan, Flathead and Mission faults.

Eardley (1947, p. 1176) in a generalized study of trenches in the Rocky Mountains noted that all the trenches studied were closely associated with high angle faults and were either graben or rotated block type structures. These high angle faults were found to post-date the older Laramide folds and thrusts.

Local Structure

Previous Structural Investigations

Although very little structural investigation has been carried out in the Whitefish Range, considerable attention, especially in Canada, has been directed to the Rocky Mountain trench and to the North Fork of the Flathead Valley. The surfaces of both depressions, however, are mantled with thick glacial debris and only scant evidence of a mode of origin is available. Many authors have suggested possible causes of the depressions, however, few are in agreement (see fig. 4).

Daly (1912, p. 106) and Schofield (1915, p. 52; 1921, p. 73-81) considered the Rocky Mountain trench to be a graben or at least the product of normal faulting. The normal fault along the east side of the trench was believed to have dropped Devonian strata adjacent to or below the Precambrian strata of the Whitefish Range. Daly (1912, p. 99) also suggested a genetic connection between the trench and the shore line of middle Cambrian to Devonian Seas. Daly (1915, p. 113-114) later considered the trench to be the result of normal faulting along a continuous fault zone with accompanying scission and shifting. Shepard (1922, p. 138-139) believed that opposing thrust faults or overturning of two mountain wedges on each side of and toward, the trench produced the depression. The fault along the east side of the trench, which was considered by Daly and Schofield to have been a normal fault, was believed by Shepard to have been an east dipping underthrust. Later Shepard (1926, p. 640) suggested that the trench

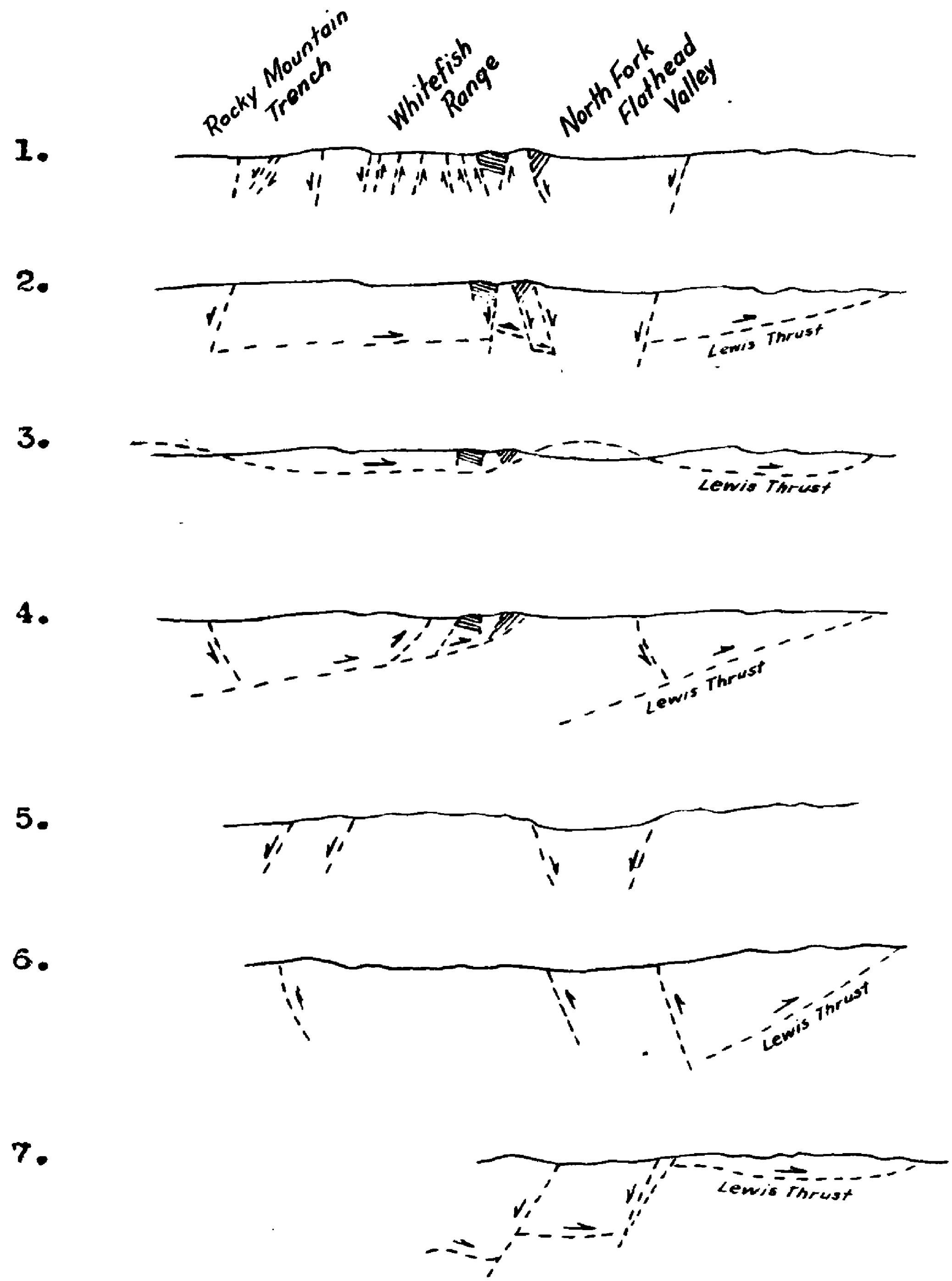

Figure 4. Interpretations of structure across the Whitefish Range and North Fork of the Flathead Valley. 1. Daly (1912). 2,3,4. Link (1935). 5. Pardee (1950). 6. Clapp (1932). 7. Clark (1954).

was eroded along a horst. Clapp (1932, map) mapped the Swan fault, a high angle east dipping underthrust that borders the west edge of the Swan Range, as continuing along the southwest edge of the Whitefish Range within his map limits. Evans (1933, p. 145) noted thrust faults and folds overturned toward the trench in the bordering ranges on each side of the trench. The thrust on the east side was interpreted as an underthrust and Evans believed the trench has been eroded along the line of intersection between the thrust and underthrust faults. Link (1935, p. 1466, figs. 1 and 32) believed that an east dipping underthrust met a west dipping overthrust at depth. The block east of the underthrust was then wedged upward while the block west of the underthrust was relatively depressed by a modified ramp action to form the Rocky Mountain Trench. Pardee (1950, map) hypothesized a normal fault along the western range front and called it the Whitefish fault. A second normal fault along the valley of Whitefish Creek extended the range front fault to the southern terminus of the Whitefish Range.

In explaining the North Fork of the Flathead Valley, Willis (1902, p. 344) suggested a normal fault along the east side of the valley. Daly (1912, p. 90), MacKenzie (1916, p. 5) and Rose (1918, p. 35) explained the valley as a graben. Clapp (1932, map) mapped the Flathead fault, as a high angle east dipping underthrust bordering the west side of the Flathead Range and continuing along the east front of the Whitefish Range as far north as Whale Buttes. Link (1932, p. 787, fig. 1) proposed an inverted wedge or modified ramp interpretation as the cause of the depression. Link (1934, p. 1464-66) later believed the possibility that the valley was a window in the Lewis overthrust warranted serious consideration. Hume (1944, p. 59), although he entertained the window theory, considered it unlikely. Erdmann (1947, p. 141) noted a progressive decrease in throw to the northwest along the Flathead fault and believed that this evidence, combined with physiographic relationships between adjacent mountain ranges, suggested that the North Fork of the Flathead Valley was the depressed extension of the Flathead Range block. Pardee (1950, map) believed that a normal east dipping fault was indicated along the Whitefish Range front. Clark (1954, p. 109) returned to Willis' interpretation of west dipping normal faults as the basis of the North Fork of the Flathead Valley structure. Both Erdmann (1947, p. 199) and Clark (1954, p. 104) believed the Lewis thrust had its roots in the Whitefish Range west of the North Fork of the Flathead Valley.

Daly (1912, map 75A) showed a system of north-south trending normal faults in the Whitefish Range along the International Boundary.

Present Investigation

The structure of the area examined is rather complex and only in the northeast portion of the Whitefish Range did stratigraphic knowledge permit an interpretation.

The Whitefish Range is essentially a broad anticline trending northwest-southeast and faulted along the northeast and southwest limbs. Associated with these major faults are numerous minor faults and folds that will require considerable attention before the complete structural history of the range can be worked out.

The range front fault along the west side of the Whitefish Range is indicated in the northwest portion by the presence of Devonian strata in the Rocky Mountain trench, structurally lower than the adjacent Precambrian strata of the Whitefish Range. The fault plane, however, is covered by glacial debris and its attitude is unknown. Further specific evidence for the fault was not observed to the southeast but the steep straight face of the range suggests that a fault exists under the thick glacial mantle that covers the valley floor and the lower mountain slopes.

Along the east front of the Whitefish Range the Flathead fault has been observed as far north as Apgar Mountain where Erdmann (1947, p. 188) noted the fault along the northeast margin of that mountain. To the north all further trace of the fault is lost under the glacial debris of the North Fork of the Flathead Valley, however, the overly steepened lower slopes along the front of the range suggests that the fault is continuous to the north along the range front.

Insufficient evidence was found along the margins of the Whitefish Range either to substantiate or repudiate any of the previous structural theories. Topographic details and local evidences of faulting indicate the presence of range front faults but specific evidence concerning the nature of such faults and their direction of dip is hidden under the glacial debris of the North Fork of the Flathead Valley and the Rocky Mountain Trench.

In the Whitefish Range, Daly (1912, map 75A) included in a system of normal faults along the International Boundary a series of faults in the northeast part of the map area that dropped two separate blocks of Paleozoic strata into contact with Precambrian strata (see fig. 4). Further faulting within the easternmost Paleozoic block dropped Mississippian limestone structurally lower than Devonian limestone.

The writer's evidence indicates that a low angle thrust fault of considerable magnitude is responsible for the present position of the strata (see pl. II). The Precambrian rocks were apparently thrust from the west and rode over the Paleozoic rocks. Later erosion left a portion of the Precambrian rocks as an outlier overlying the Paleozoic rocks. This outlier apparently appeared to Daly as a block separating the two down thrown blocks of Paleozoic sediments. Along the margins of the North Fork of the Flathead Valley within Daly's easternmost Paleozoic block there is little doubt that the occurrence of Devonian limestone overlying Mississippian limestone represents the overturned limb of an anticline rather than down faulted Mississippian strata adjacent to or below Devonian strata (see Pl. II).

Lewis Overthrust

The presence of oil seeps in the Belt series along the east side of North Fork of the Flathead Valley suggests the possibility that high angle faulting along the valley intersects the Lewis thrust and that oil has moved along the high angle fault from Paleozoic and/or Mesozoic rocks beneath the Lewis thrust. As previously stated several authors have expressed the opinion that the Lewis thrust underlies the valley and underlies or has its roots in the Whitefish Range.

According to Clark (1954, p. 109) the Tertiary beds in the North Fork of the Flathead Valley were deposited in an elongate downfaulted block after thrust faulting as they show no evidence of having been overridden by a thrust sheet. The eastward dip of the Tertiary beds along the west side of the North Fork of the Flathead Valley is interpreted as drag and indicates further relative depression of the valley block.

If the Lewis overthrust underlies the North Fork of the Flathead Valley, the possibility exists that the thrust fault along the east edge of the Whitefish Range may be an exposure of the Lewis thrust. Assuming this to be the case subsequent depression of the North Fork of the Flathead Valley block carried the plane of the Lewis thrust well below the surface of the valley. Simultaneous or subsequent tilting of the Whitefish Range block exposed the trace of the thrust along the northeast edge of the Whitefish Range.

Structural History

Although the entire structural pattern of the Whitefish Range was not worked out, the structure as observed along the east side of the range and the general agreement among various authors that the North Fork of the Flathead Valley is a depressed block implies a certain sequence of orogenic activity in the range. This sequence probably conforms to that given by Erdmann (1947, p. 78) and described earlier under the sub-heading 'Regional Geology.'

The overthrust relationship of Precambrian sediments on Paleozoic sediments and the folding within the sediments suggests that compressive forces first uplifted and folded the strata of the area, then broke them along a low angle fault plane, thrusting the Precambrian Belt rocks onto the Paleozoic rocks. Later faulting resulted in the development of the North Fork of the Flathead Valley and the relative uplift of the Whitefish Range. Still later movements resulted in the tilting of the Tertiary beds of the North Fork of the Flathead Valley, and may have further uplifted and tilted the Whitefish Range Block.

ECONOMIC GEOLOGY

Coal has been mined in or adjacent to the mapped area and deposits of phosphate rock, clay, limestone, oil shale, and copper have been reported but have never been exploited. Oil and gas seeps have made prospecting intriguing and have created hopes that commercial quantities may someday be found.

Coal

Lignite coal seams are found in the Tertiary beds of the North Fork of the Flathead Valley. An area known as the Coal Banks is located in Sections 19, 20, 29, and 30, T34N, R20W and three claims of unknown status are at present registered with the General Land Office. Evidence of former workings are present but apparently no operations have been carried on for many years. The North Fork Coal Mine in Sec. 33, T34N, R20W has been more recently in operation and produced, according to Montana Bureau of Mines (1940, p. 25), about thirty tons of coal per day. Adverse weather conditions during the winter months limited production to the more favorable seasons. The coal was hauled by truck to Columbia Falls and Kalispell and sold locally. Because of the slacking character of the coal, its high ash content and low heating value, the long haul to market, and the seasonal restriction on mining, the economic value of the coal beds is limited and it is doubtful if any commercial importance can be attached to them.

Coal has been reported in commercial quantity in the Kootenai formation, a few miles north of the International Boundary. Rose (1917, p. 35) stated that seams of 7, 8, 4, 36, and 25 feet have been proven along Cabin Creek approximately six miles north of the International Boundary and there are local reports of coal in the vicinity of Cauldrey Creek three miles north of the Boundary. MacKenzie's analyses (1916, p. 46) showed the coal to be of high rank and to possess very good coking qualities.

It seems probable that along the west edge of the map area near the International Boundary, the coal bearing formation should underlie the glacial debris east of the Carboniferous exposures, provided a normal stratigraphic sequence occurs there. The thickness of the overlying glacial debris may, however, limit the future commercial value of the coal even though it may be present south of the Boundary.

Bituminous Shale

Layers of so called oil shales have been found within the Kishenehn formation on Cauldrey Creek, a few miles north of the International Boundary and they may occur in the North Fork of the Flathead Valley south of the Boundary. Except for a few random cobbles among the gravel of the North Fork of the Flathead Valley, none of the oil shales were observed in the map area. They are believed, however, to occur east of the North Fork of the Flathead River and may underlie the glacial debris west of the river.

MacKenzie (1916, p. 34-35, 48-49) has described the bitumen bearing beds along Cauldrey Creek in some detail and noted as a marked characteristic the strong bituminous odor given off by the rocks when struck, rubbed, heated or when brought into contact with hydrochloric acid. He also noted impregnations of yellow, brown and black material which he thought were evaporated petroleum residues. These impregnations graded into irregular yellow, brown and black spots of which the lighter colors were transparent while the deeper colors in strong transmitted light has a reddish tint suggestive of petroleum. The bitumen was also observed to take the form of spheres from sub-microscopic to .04mm. in diameter. The spheres were arranged in swarms of a few dozen of the larger to several scores of the smaller sizes. MacKenzie believed these spheres to represent small drops of petroleum that had been segregated under the influence of surface tension in water saturated rocks, yet were unable to migrate to any considerable distance owing to the very dense character of the enclosing material. He could not determine their present degree of fluidity but noted that they exhibited no migratory tendencies in their present condition and environment. MacKenzie assigned the source of the bituminous material to the soft parts of mollusks whose shells are in close association with the bitumen.

The oil shales as such are of no present commercial value and it is doubtful that any future value can be assigned to them.

Phosphate Rock

Phosphate has been reported by Telfer (1933, p. 577-584) within the Fernie formation and at the top of the Rocky Mountain formation, along the North Fork of the Flathead Valley near the International Boundary. As the Rocky Mountain formation is partially exposed along the east mountain front near the Boundary, and a considerable section of the Fernie formation is exposed on Cauldrey Creek just north of the Boundary, it seems reasonable to assume that the Rocky Mountain-Fernie contact and the Fernie formation are present beneath the glacial debris along the mountain front. Since the phosphate bearing formations are buried under an unknown depth of glacial debris any future commercial interest in the phosphate will probably depend upon the grade and amount of phosphate found in the exposed phosphate bearing formations adjacent to the map area.

Metalliferous Deposits

Metalliferous deposits of commercial value are not known in the Whitefish Range. Prospecting, probably motivated by the presence of green copper carbonate stain on parts of the Purcell basalt, has been carried on without success in the northwest corner of the range, and numerous prospect pits and several abandoned workings are present in the vicinity. All of the old prospect cabins were in bad repair at the time of the writer's visit and none showed evidence of recent occupancy. No information was available concerning the operations but from the appearance of the abandoned workings it is extremely doubtful if any were operated profitably.

Gravel and Sand

Extensive deposits of gravel occur in the glacial debris of the valleys and in terms of local and probable local demand the supply seems inexhaustible. Local deposits of sand occur in the debris probably in sufficient quantities to supply any future demand of the area.

Clay and Building Stone

Clay occurs in the Tertiary lake beds of the North Fork of the Flathead Valley but the amounts and suitability of these clays for building or other purposes has never been determined.

Abundant limestones occur throughout the Whitefish Range in the

Siyeh, Rundle, Palliser and Kishenehn formations. The Rundle and Palliser formations are apparently the only ones of sufficient purity to be used commercially. Their remoteness, however, and the abundance of other more accessible limestones eliminate all but faint future values.

Impure and highly siliceous limestones and dolomites are used in the manufacture of rock wool insulation. The Siyeh limestone may be sufficiently impure and contain the other properties necessary to classify it as a source of rock wool. If the Siyeh should be lacking in some properties a composite wool rock might be compounded from the Siyeh and the calcareous facies of the Kishenehn formation.

Building stone has never been quarried in the area, although some of the argillites, limestones and basalts are probably of adequate quality to be quarried if ever the demand for such arises. Much of the Belt rocks are closely jointed, but less jointed portions are present in sufficient quanties to supply all apparent future needs.

Oil and Gas

Seeps of high gravity oil have been known in the North Fork of the Flathead Valley in the vicinity of the International Boundary since before 1900. Sporadic interest in the oil possibilities of this area, spurred by the presence of these seeps, has resulted in the drilling of a number of wells, two of which were south of the Boundary and none of which were commercially productive.

The seeps occur along the east side of the valley and their alignment suggests that they lie along a fault plane. Erdmann (1947, p. 202) believed this fault to be the Roosevelt or Sage Creek fault and proposed transverse faults to be responsible for the seeps that are not in alignment as those at Kintla Lake and the reported seep near the mouth of the Kishenehn Creek.

Seeps have also been reported along the west side of the valley. A very thin oily film was observed on ponded water in the vicinity of some of the reported seeps but this film was believed to be the result of the decomposition of organic matter rather than of seeping oil. Nothing that could be classified as a true oil seep was observed along the west side of the valley.

Although the stratigraphic sequence beneath the North Fork of the Flathead Valley is unknown, it is necessary to postulate a source of the oil seeps in rocks younger than the Precambrian as the possibility that the present seepages are fed from source beds within the Precambrian series is improbable.

Link (1932, p. 791-996), comparing the physical characteristics of the oil from the seeps with the phsical characteristics of Turner Valley oil, noted the similarity between the two and concluded that the seeping oil is probably derived from Devonian, Carboniferous and possibly Jurassic beds, while Upper Paleozoic porous limestones and dolomites may be the reservoir rock, or may have acted as "carrier beds."

MacKenzie (1916, p. 48-49), although considering it unlikely, advanced the possibility that the seeps may have been derived by migration from the bituminous Tertiary sediments. It seems more probable, however, that the Tertiary bitumens may have been derived from the escaping petroleum of the seeps.

The structure of the North Fork of the Flathead Valley is, like the stratigraphy, hidden under the glacial debris that overlies the valley floor. Link (1932, p. 787, fig. 1) believed the valley to be underlain by Mesozoic strata which in turn were presumably underlain by Paleozoic strata. The oil was believed to have migrated along a high angle underthrust which breached the Paleozoic resevoirs. It is difficult, however, to visualize how soft incompetent rocks of the Mesozoic series could be forced under the massive more competent rocks of the Belt series of the

Livingston Range. It appears more probable that Precambrian strata should underlie the North Fork of the Flathead Valley. These Precambrian strata were presumably thrust over Upper Paleozoic and Mesozoic rocks and the entire block that now makes up the North Fork of the Flathead Valley was depressed in relation to the Whitefish and Livingston Ranges. In this case the oil seeps, although they may have their source in Paleozoic and, or Mesozoic rocks, are fed through fault planes across an undetermined thickness of Precambrian strata.

No attempt can be made to evaluate the oil possibilities of the area. The presence of the oil seeps and the grade of oil connected with them are encouraging factors. Drilling results, however, have been discouraging. Prospecting for oil in the vicinity is continuing and will probably continue as long as the seeps inspire the hopes of commercial production.

PLATE I

A. Rocky Mountain -Rundle contact exposed along Yakinnikak Creek Road.

B. Steeply dipping Tertiary lake beds exposed along the west side of the North Fork of the Flathead River, north of the mouth of Coal Cr.

C. View eastward from Whitefish Range across the Valley of the North Fork of the Flathead River at the International Boundary. Livingston Range in the background.

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